MC REPORT 1

BOMEX

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OCEAN SCIENCE PROGRAM
MAURY CENTER FOR OCEAN SCIENCE
Department of the Navy
Washington, D.C.

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U.S. NAVY PARTICIPATION IN THE BARBADOS OCEANOGRAPHIC AND METEOROLOGICAL EXPERIMENT

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Foreword

Every aspect of the sea – its motions, its chemical and physical properties, its life forms, its boundaries, its energy content – affects the operations of ships, weapons, and specialized equipment of the Navy. The ability of the Navy to perform its primary mission depends on an understanding of these many aspects of the oceans. As systems become more sophisticated, and as Navy operations below the surface reach greater depths, this dependence becomes more apparent. In recognition of this dependence, the Navy actively pursues research in all phases of marine science and technology.

Oceanography's present challenge is immense, because years of scientific investigation have yielded no more than a first-order approximation to a description of the ocean. The Barbados Oceanographic and Meteorological Experiment (BOMEX) will provide an opportunity to investigate the magnitude of the departure of the real ocean from our present concepts based on steady-state approximations. More realistic concepts will result in refined ASW environmental prediction models. The experiment will provide opportunity to investigate the responses of the sea-surface boundary to measured thermal and mechanical forcing functions in the atmosphere and to observe and measure the translation of these responses vertically and horizontally through the ocean. BOMEX will also furnish an opportunity to investigate the spatial coherency of water and air motions to distances in excess of 500 kilometers at a number of depth and height levels.

As noted by the Oceanographer of the Navy in his report on the Ocean Sciences Program* of the U.S. Navy,

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*"The Ocean Science Program of the U.S. Navy, Accomplishments and Prospects," Office of the Oceanographer of the Navy, Alexandria, Va., p. 102, June 1967

> The progress in the study of ocean circulation and internal waves, as well as the requirements for a general attack on the problems of air-sea interaction, have long made obvious the need for complex and extensive observational networks at sea. These, in turn, require advanced engineering design and development on a scale not previously pursued in scientific programs in physical oceanography ... These plans require scientific resources beyond a single institution to supply, and they also require a major effort in formulation and execution. Suitable combinations of research groups are now working on program studies, and it is anticipated that the next few years will see major efforts in the Navy Ocean Science Program. It seems clear that this effort can be useful to other programs of the Federal Government in furthering its national and international objectives. Cooperative planning with with other federal agencies to this end has already begun.

The Navy participation in BOMEX represents a significant contribution to a cooperative federal program of ocean exploration. It brings together not only the Navy in-house capabilities for scientific research in the field of air-sea interaction, but also those of Navy contractors from universities, institutions, and private industry. This coordinated teamwork is expected to lead to a far better understanding of the phenomena in question than if the several problems were approached independently and individually. At the same time, BOMEX affords the investigators the opportunity to learn first hand from each other the techniques, problems, and successes which may affect their own work.

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INTRODUCTION

BOMEX Objectives

The Barbados Oceanographic and Meteorological Experiment (BOMEX) is a large-scale air-sea-interaction field experiment scheduled to be conducted in the vicinity of the island of Barbados in late spring and early summer 1969. This coordinated experiment will draw upon the talents and resources of federal agencies and academic institutions to conduct a concentrated environmental study of the ocean and atmosphere in an area of approximately a five-degree square of latitude and longitude located about 100 kilometers east of Barbados (Fig. 1).

The primary objectives of BOMEX are to undertake an area study, that is, to study the total ocean-atmosphere system within a limited oceanic area having known, representative, and conservative characteristics, and also to develop a pilot field study that may be used for planning and executing similar experiments in the future within the framework of the long-range Global Atmospheric Research Program (GARP) of the 1970's. The air-sea-interaction objectives of the experiment are (1):

(a) Study of the vertical flux of momentum, sensible heat, latent heat, radioactivity and other properties at the interface and the horizontal transport of these properties through the lateral boundaries of the observational array.

(b) Study of the vertical and horizontal divergence of these fluxes within the interior of each fluid.

(c) Study of the feasibility of parameterizing the area wide integral of at least the surface fluxes from conventional observation at the fixed corners of the array.

Related studies in physical oceanography and micro- and mesoscale meteorology also are to be undertaken. BOMEX will provide an excellent opportunity to conduct related experiments within a well-controlled observational network. It fact, an underlying motivation for this coordinated experiment is the fact that no single agency possesses the material resources and scientific manpower required to execute a study of atmospheric-ocean interaction processes simultaneously on the micro-, meso-,

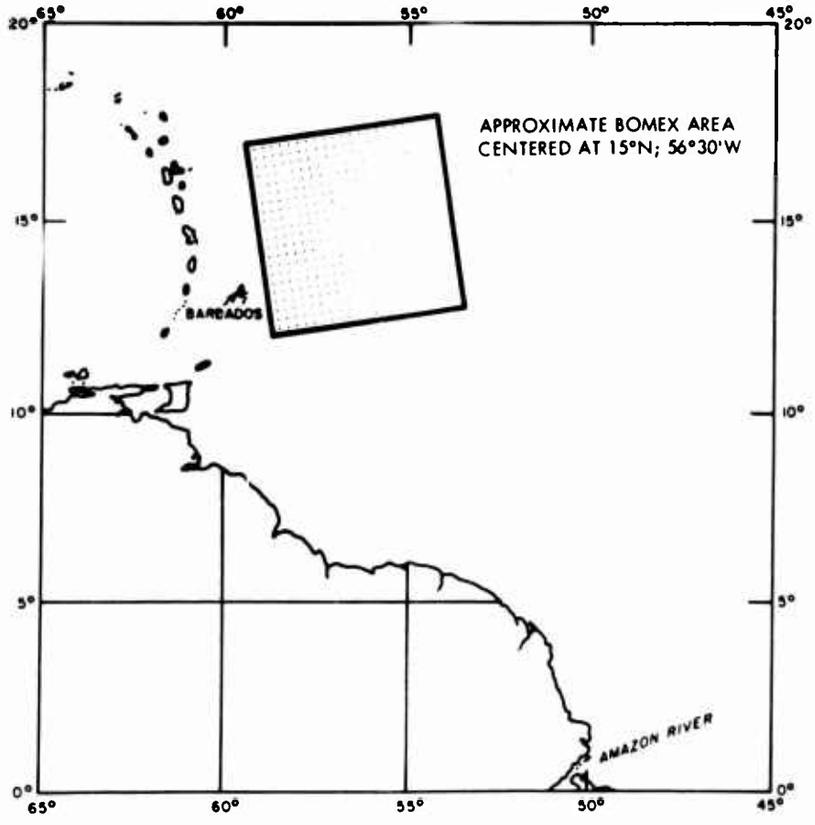

Figure 1 – Geographic limits of BOMEX area

and synoptic scales, and that such experiments are required for substantial advances in worldwide weather and oceanographic forcasting.

The BOMEX experiment is concerned primarily with the study of air-sea interaction. The principal interest of the Navy in this connection lies in the zone between the base of the thermocline and the gradient wind level. Atmospheric effects have a major role in modifying the environment in this zone. These environmental effects, which include currents, thermal structure, and sea state, impose vital constraints on the performance of weapon systems, detection devices, and naval platforms. The study of air-sea interaction has developed to a point where massive synoptic experiments are required to improve our ability to predict "undersea weather." This ability is essential to support the improvement and use of naval systems. The resource requirements for this type experiment cannot be met easily by any one federal agency. Inasmuch as environmental information is needed for the missions of most of the agencies involved in marine activity, the BOMEX experiment is almost ideal for interagency cooperation.

General Description of the BOMEX Site

The site selected for this intensive study is in a region where energy exchange between the atmosphere and the ocean is particularly significant. The region is a sink for solar radiation reaching the earth's surface. The ocean acts as a reservoir which supplies large amounts of energy in the form of latent heat to the atmosphere. The winds in the Barbados area are governed by the general North Atlantic circulation pattern, which undergoes marked seasonal changes. In winter (November through January), the Bermuda-Azores high moves to its northernmost position, and the winds are generally from the northeast. As summer approaches, the winds gradually shift to the east and increase in speed. The southernmost portion of the area to be studied is distinguished by periodic interruptions of wave-like atmospheric perturbations (easterly waves), which move westward at speeds up to 6 meters per second. During early summer, when BOMEX is scheduled, few fully developed storms transit

the area, and the likelihood of the experiment being disrupted from this cause is minimal.

The BOMEX area, mapped on a bathymetric chart, is shown in Fig. 2. The area is centered over the Guiana Basin, where maximum water depths are about 2900 fathoms. The southeastern part is uniformly deep and the ocean floor has topographic characteristics of an abyssal plain. The western part of the area overlies the rise and slope provinces seaward of the Lesser Antilles Arc. A low-relief, rise-like feature extends east southeastward into the northern part of the area.

Line AA′ on Fig. 2 marks the track of a subbottom profile through the BOMEX area. The accompanying profile (Fig. 3) shows, from right to left, the outer crest of the Lesser Antilles Arc, the steep slope, the continental rise, an outer rise, and the thickly sedimented Guiana Basin, with numerous outcroppings of underlying rock.

Figure 4 shows temperature, salinity, and density to a depth of 700 meters from data obtained in September 1967 in the BOMEX area. The salinity maximum is at about 125 meters depth, and very stable density structure exists above 200 meters depth.

Surface currents in the area generally set west to northwest throughout the year at mean speeds of about 0.7 knot (35 cm/sec). A series of subsurface current measurements obtained over a 24-day period in September and October 1967 indicates a westward flow with speeds of 15 to 20 cm/sec at 120 meters depth, northwesterly flow with speed of 2 to 3 cm/sec at 1500 meters depth, and easterly flow with speeds of 7 cm/sec at 4500 meters depth.

Historical Review

Among other recommendations in its 1962 report (2), the National Academy of Sciences Joint Panel on Air-Sea Interaction recommended that special area studies be undertaken to provide experimental facilities for field test of equipments and for evaluation of hypotheses concerning the behavior of boundary layers and the air-sea interface.

Figure 2 – Bathymetry of BOMEX area. Depths are given in fathoms.

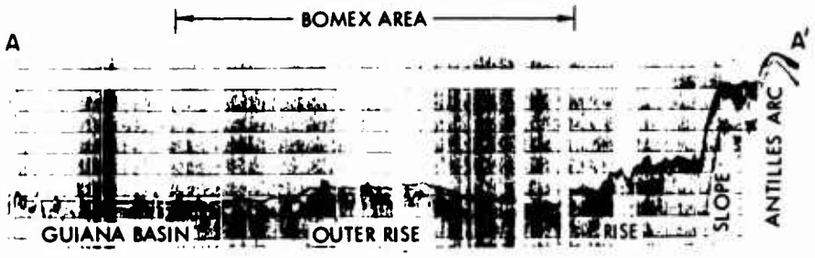

Figure 3 – Subbottom profile in BOMEX area

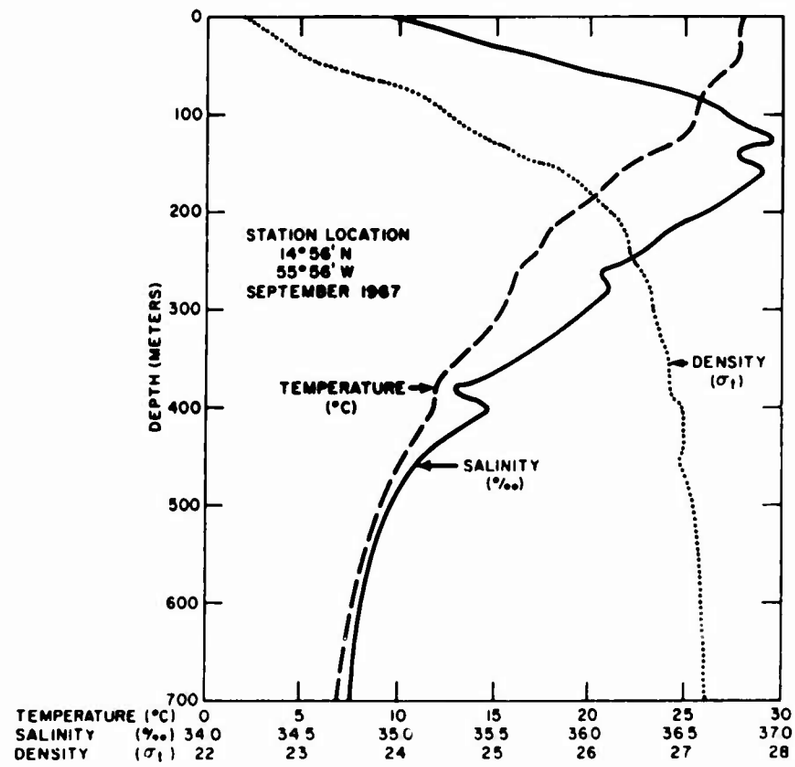

Figure 4 – Profiles of temperature, salinity, and density in the BOMEX area

More recently, the President's Science Advisory Committee, Panel on Oceanography, emphasized the need for area studies in its 1966 report (3). In describing the prediction of large-scale atmospheric behavior and the associated need for relating fluxes of heat, momentum, and water vapor at the sea surface to the scale of weather systems, the panel noted the need for measurements over extended oceanic areas in a program utilizing fixed platforms, buoys, aircraft, and possibly submarines. Both the national and international planning of GARP also has indicated the necessity for area studies. The National Academy of Sciences Panel on International Meteorology Cooperation has mentioned in a report (4) that research must be undertaken to relate boundary fluxes to macroscale observations for areas of about 250,000 square kilometers. An international study conference on GARP, convened in Stockholm in 1967, also recommended that detailed studies be made of the structure of atmospheric boundary layers in an attempt to relate turbulent fluxes to synoptic scale parameters; BOMEX was cited as such a project.

While most of the reports concerned with air-sea interaction research have stressed its benefit to atmospheric prediction, the Federal Plan for Marine Environmental Prediction (5) prepared by the National Council on Marine Resources and Engineering has recommended continued efforts in air-sea interaction studies aimed at determining the effects of changes of large-scale atmospheric patterns on the convergence-divergence zones in ocean surface layers and in turn the effect of these changes on subsurface thermal structure. Observations of the effects are to receive major emphasis in BOMEX.

The development of BOMEX as a coordinated air-sea interaction experiment involving the various federal agencies has evolved from a basic plan of the Department of Commerce, based upon its own resources and capabilities. This plan (6, 7) resulted from an assigned responsibility of the Department of Commerce to develop area studies within the federally sponsored air-sea interaction efforts. The assignment was part of action by the Federal Council for Science and Technology to stimulate an active and productive federally supported program. The

basic Department of Commerce plan in response to this assignment was submitted to the Interagency Committee on Oceanography and the Interdepartmental Committees for Atmospheric Science of the Federal Council for Science and Technology in March 1967 for approval and action by other federal agencies. At that time, the Navy, through the Department of Defense member on ICAS, proposed that it assume a leading responsibility for the oceanographic aspects of BOMEX. Accordingly, the Navy has developed its program for the ocean environment and is coordinating with the oceanographic aspects of other agency programs for an integrated oceanographic study within BOMEX.

Organization of BOMEX

The overall coordination for BOMEX remains the responsibility of the Department of Commerce. A BOMEX Project Office has been established within the Office of World Weather Systems in the Environmental Science Services Administration. It serves as a focus for planning and coordinating the experiment. The National Academy of Sciences also provides guidance to the Project Office through an advisory panel under the chairmanship of Dr. Robert Fleagle, University of Washington.

Several federal agencies are developing their projects for BOMEX. These in turn are being coordinated with the Project Office for an integrated program. The Director of the Maury Center for Ocean Sciences, Dr. J. B. Hersey, has the responsibility for developing the plan for Navy participation in BOMEX involving both in-house and contractor elements of the Navy's Ocean Science and Technology programs.

NAVY PARTICIPATION IN BOMEX

Programs

The Navy participation in BOMEX will include both in-house and contractor programs. Navy programs will emphasize the study of the general problem of the temporal variability of the oceans. Recent advances in theoretical research and measure-

ment technology have shown that the ocean, at all levels, is more restless than had previously been evident from interpretation of classical oceanographic observations. This restlessness is the result of external and internal processes acting to change the thermal fields, the fields of chemical properties, and the fields of motion.

It is the goal of the Navy programs to enhance the understanding of basic processes in low latitudes, such as the occurrence of internal gravity waves, tidal oscillations, and inertial oscillations and their relative energy levels; the turbulent fluxes of momentum, heat, and dissolved substances in the near-surface region of the ocean; and the characteristics of ocean currents at all depths.

The specific scientific areas with which the Navy programs will be concerned are as follows:

1. Thermal structure
2. Microscale energy processes
3. Surface-wave generation
4. Current-structure variability
5. Environmental-prediction evaluation

Thermal Structure—For years the Navy has maintained research programs aimed at documenting and rationalizing the ocean thermal structure from microscopic to planetary scales. This interest in thermal structure results from the fact that temperature is the principal time-dependent, controlling factor in the propagation of sound in the ocean. Underwater sound is the Navy's primary energy form in weapons-system control, surveillance, and object location. The ocean, far from being the stylized medium of the classical acoustics textbook, is a restless, nonuniform fluid medium whose characteristics result in a wide spectrum of acoustic propagation anomalies ranging from large-scale horizontal and vertical refraction to subtle but important small-scale turbulent effects causing signal degradation or enhancement. It is anticipated that the thermal-structure research program proposed as a cooperative effort in BOMEX will provide new insights into the controls on, the ocean's response to, and ultimate distribution of thermal energy

TABLE 1
Thermal-Structure Research

Measurement	Objective	Instrument	Platform	Auxiliary Data Required	Sponsor
Measurement of IR temperature at optimum depth of 0.025 mm and 0.075 mm	Total heat flux from sea surface	Airborne twin wave length radiometer (3.50-4.05 μ) (4.45-5.10 μ)	Aircraft or FLIP	Sea surface temperature, meteorological data	ONR (Contract) McAlister SIO
Sea surface thermal patterns	Determine thermal patterns at sea surface as indicative of convective processes	Infrared line scanner	Aircraft, surface ship, or FLIP	Temperature vs depth Local meteorological conditions	ONR (Contract) Foster Yale
Quasi-synoptic surface temperature	Surface temperature distribution and boundary locations	Airborne radiation thermometer	Aircraft	Sea surface temperature from ship	NAVOCEANO James
Depth of all whole degree isotherms between surface and 240 meters	Determine spatial distribution of isotherms in upper layers	Towed thermistor chain	Ship	Meteorological data	NUWC Smith
Ocean Station salinity, temperature, depth	Compare classical geostrophic technique with synoptic measurements	STD instrument Nansen casts	Ships	Buoy temperature and current data	NAVOCEANO Mazeika
Turbulent temperature and vertical velocity in sea from 0 to 15 m	Obtain Covariance between turbulence vectors Estimate heat transfer	Fast response thermistor and vertically directed impeller	Stable platform	Meteorological data, wave data, water temperature	NUWR&ES Shonting

incident at the air-sea boundary. Table 1 shows the proposed thermal-structure research programs, together with objectives, measurement, instrumentation, platform, auxiliary data requirements, and the sponsoring laboratory and principal investigators.

Microscale Energy Processes—The ocean receives solar energy in excess in the tropical regions, and releases it near the poles The earth's rotation, tidal effects, and boundary effects perturb orderly flow, and introduce complexity. Finally small-scale

phenomena become significant because they may be present over large areas, and thus disrupt still further the theoretical picture of energy exchange. Darkness, cloudiness, water transparency, thin surface films, bubbles from "white caps," evaporation, and stability all play a role in the energy budget.

As a consequence we observe a complex sequence of processes of energy transfer. In attempting to arrive at an understanding of these processes at the higher frequencies, Navy investigators have designed and developed a number of sophisticated acoustic, thermal, and mechanical sensing techniques, and two virtually stable platforms which can be deployed into the ocean to serve as measurement platforms. The Maury Center for Ocean Science has arranged for one of these, FLIP (Fig. 5), to be deployed into the BOMEX area to serve as a measurement platform for the purpose of studying microscale energy processes. These measurements will include wind-stress measurements by hot wire,

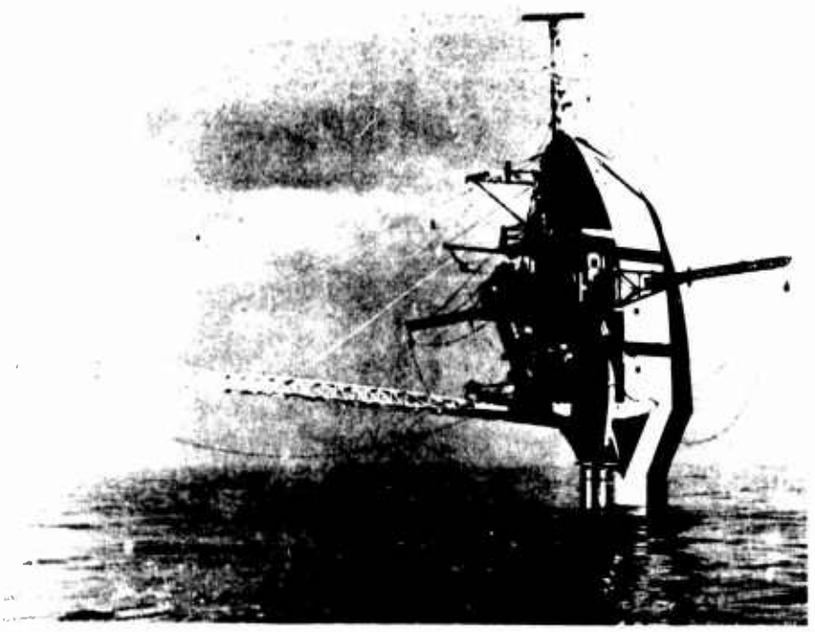

Figure 5 – Floating Instrument Platform (FLIP). In the vertical position shown, its draft is 300 feet

sonic, and mechanical anemometry, providing opportunity, among other things, to compare distinct approaches to the estimation of this important oceanographic parameter. At the same time, the measurements of horizontal and vertical turbulent kinetic energy will be attempted in the near-surface layer of the ocean using fast-response thermal and mechanical instrumentation. It is anticipated that the microscale energy-transfer research program will provide better estimates of turbulent energy flux through the ocean surface and the upper layers of the ocean than heretofore available. Table 2 shows the proposed microscale energy processes research programs.

Surface-Wave Generation—Winds blowing over the water generate waves, and it seems a remarkable fact that the actual mechanism is still unknown. Several promising theoretical approaches have been proposed in the past few years, attempting to provide a link between the driving force (the turbulent atmosphere above) and the response function (the moving sea-surface boundary below) which we call waves. Quantitative verification of the wave-making process is still obscure, partly because of the extreme difficulty involved in setting up controlled experiments. Occasionally, just the right conditions occur to permit execution of semicontrolled experiments. These experiments are being done as part of the Navy's in-house and contract research programs, but they do not have the extensive deep-water supporting data available that BOMEX will provide.

The persistence and steadiness of the trade-wind regime in the BOMEX area provides acceptable experimental conditions for investigating the spectral properties of wind-generated waves. On the windward side of Barbados, verification of the concept of a "steady-state" or "fully developed" sea can be checked; on the leeward side, well-documented sequences of limited fetch observations can be obtained. Now these wave data, characterized by as close to laboratory-controlled conditions as possible in the natural environment, can be obtained by radar wave-profiling capability aboard Navy aircraft. Additionally, a method recently developed by the Naval Research Laboratory for estimating directional wave spectra through optical transforms of sea-surface photographs will be tested.

TABLE 2
Microscale Energy Processes Research

Measurement	Objective	Instrument	Platform	Auxiliary Data Required	Sponsor
Measurement of Reynolds fluxes	Determine turbulent structure in lowest 10 m of atmosphere	Hot-wire anemometry	Stable platform	Meteorological data	ONR (Contract) Portman U. of Mich.
Turbulent stress	Correlation of lower boundary layer stress and sea-glitter patterns	Sonic anemometry	Stable platform	Meteorological data, stable glint patterns	ONR (Contract) Stewart U of BC
Wind-stress estimates from mean-square values of horizontal wind-speed gradient	Determine structure, function, and momentum fluxes	Paired hot-wire anemometers	Stable platform	Meteorological data	ONR (Contract) Franceschini Texas A&M
Wind-stress estimates from mean-square values of horizontal wind-speed gradient	Determine structure, function, and momentum fluxes	Paired-cup anemometers	Stable platform	Meteorological data	NAVOCEANO Deleonibus
Estimates of vertical shear in upper layers of water	Determine injection of mean and turbulence kinetic energy by wind stress	Vertical array of horizontally ducted impellers	Stable platform	Wind waves, wind stress	NUWR&ES Shonting
Measurement of waves and horizontal particle velocities in crest-trough region	Relationship between wind fluctuation and free-surface oscillation	Hot-film anemometer on a wave staff	Stable platform	Wind waves, wind stress	NUWR&ES Cook
Turbulent horizontal velocity and turbulent temperature in mixed layer	Estimate dissipation of kinetic energy in mixed layer and measure thermal microstructure	Turbulent flow meter and hot constant temperature anemometer	Moving ship	Meteorological data, current data, thermistor chain data	NUWR&ES Massey
Insolation, backscattering, albedo	Radiant energy exchange	Radiometers	Ship or C-54 aircraft	Spectral absorption	ONR (Contract) WHOI Saunders
Radon/Radium ratios	Turbulent flux by chemical exchange	Rd/Ra counters	Ship	Temperature structure	ONR (Contract) Teledyne Schink

TABLE 3
Surface-Wave-Generation Research

Measurement	Objective	Instrument	Platform	Auxiliary Data Required	Sponsor
Direct measurement and photographic measurement of surface waves	Determine applicability of holographic technique for obtaining surface wave spectrum	Floating wave gages and aerial photos of sea surface	Aircraft	Meteorological data, wave data	ONR-NRL Stilwell
Direct measurement of surface waves from aircraft	Test of concept of steady-state sea on windward side and limited fetch state on leeward side	Airborne radar wave profiler	Aircraft	Meteorological data	NAVOCEANO Deleonibus
Measure wind field around FLIP model	Perfect design for instrumentation of FLIP	Pitot manometers and scale model	MIT wind tunnel	None	ONR (Contract) Mollo-Christensen MIT

It is anticipated that the research programs on surface-wave generation will provide a substantial gain in our understanding of processes of wind-wave generation, by virtue of the new and unique wave-measuring techniques and the multiplicity of auxiliary meteorological and air-sea-boundary data of research which will be obtained in the BOMEX. Table 3 shows the proposed program on surface-wave generation.

Current-Structure Variability—Current measurements obtained from many sources over the past few years have emphasized the extreme variability and time-dependent nature of fluid flow at all scales of motion. After many years of relying on traditional oceanographic studies of large-scale distribution of current averages, it is now realized that little additional progress will be made unless we can identify the nature of the motion at all scales. Energy to drive these motions comes from large-scale atmospheric motions, large-surface heat sources and sinks, tidal effects, and other sources with various ranges of influence. The vertical stability of the ocean partially controls internal wave motions by imposing limits on the allowable frequencies. The effects of the earth's rotation results in motions

observed at inertial frequencies. Thus we observe a complex combination of motions which are only partially understood and has only recently been studied in any detail by spectral-analysis techniques. Strong spectral peaks appear at tidal and inertial frequencies at all depths. Occasionally, spectral peaks appear at frequencies whose origins are unknown.

The Navy, through its in-house and contract research programs, has developed considerable capability in deep-ocean mooring technology, so that at this time it is possible to plan with confidence the establishment of moored-buoy stations for sensing current and temperature fields on a continuous basis for periods of two to three months. This capability will be employed in the BOMEX to establish a series of deep-ocean moorings similar to those shown in Fig. 6, containing current and temperature sensors which will measure currents between the surface and the bottom and temperature between the surface and a depth of 1500 meters. This line of moorings will provide data to examine the spectral density of horizontal motions as a function of latitude, depth, and distance from a boundary. The data from current-meter moorings will be compared to dynamic calculations from oceanographic-station data. The current–meter data will be analysed to estimate vertically integrated water transport in the area. Such estimates may provide an insight into deep-ocean circulation, particularly deep western boundary currents. Thermistor-array data will be examined for spectral density of vertical motions as a function of latitude, depth, and distance from a boundary. Table 4 shows the proposed program on current-structure variability.

Environmental-Prediction Evaluations–The Navy Antisubmarine Warfare Environmental Prediction System (ASWEPS) stands to benefit directly or indirectly from almost all of the research projects planned for the BOMEX. The data gathered and the theories of air-sea interface processes which may be developed will eventually be utilized in oceanographic-prediction techniques. For this reason ASWEPS personnel will observe with interest the operations of BOMEX and apply the results to ASW problems. In addition, they plan to participate actively in the BOMEX by establishing an oceanographic forecasting

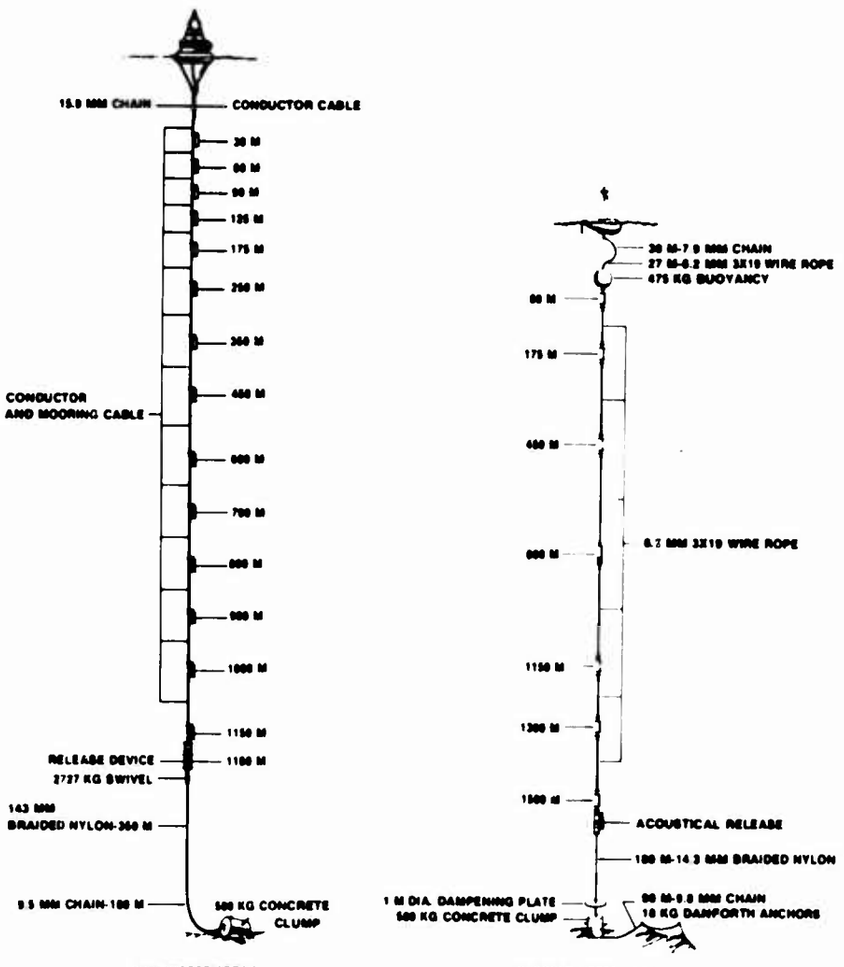

Figure 6 – Deep-ocean moorings

TABLE 4
Current-Structure Variability

Measurement	Objective	Instrument	Platform	Auxiliary Data Required	Sponsor
Time series measurements of horizontal motions	Investigate spectra of horizontal motions as function of space and time, determine horizontal current scales	Buoyed vertical arrays of current meters	Surface and subsurface buoys, and ship aircraft surveillance	Surface meteorological data – Ocean salinity temperature, depth data	NAVOCEANO Banchero
Time series measurements of vertical thermal structure	Investigate spectra of vertical motions as function of space and time	Buoyed vertical thermistor arrays	Surface and subsurface buoys, ship and aircraft surveillance	Surface meteorological data – Ocean salinity, temperature, depth data	NAVOCEANO Banchero
Track FLIP repeatedly through area	Vertically integrated near-surface flow	FLIP	FLIP	Surface winds, current data	ONR SIO

center on Barbados to issue and evaluate forecasts for the BOMEX area and to conduct aerial oceanographic surveys of the BOMEX area.

Platforms

The Navy ships and aircraft serving as the measurement platforms for the previously mentioned programs are listed in Table 5, together with tentative deployment dates, primary purpose, and sponsoring activities. Total ship time in support of BOMEX is estimated at 160 ship-days. Navy research aircraft time is estimated at 200 flying hours.

In addition to the research aircraft committed to support the oceanographic program, Weather Reconnaissance Squadron Four will conduct weather-reconnaissance flights by diverting one routine recon track (KILO Track) sufficiently to over-fly the BOMEX area. The flights will occur on alternate days, subject to other higher priority missions and required hurricane reconnaissance.

TABLE 5
Navy Platforms

Name	Type	Tentative Periods of Use	Primary Purpose	Sponsor
USNS LYNCH	AGOR	1/11/69 to 2/24/69	Exploratory oceanography, ocean stations, bathymetry cores	NAVOCEANO
USNS GILLISS	AGOR	5/22/69 to 8/5/69	Ocean stations, buoy surveillance, cooperating platform	NAVOCEANO
FLIP	Stable Platform	5/2/69 to 5/30/69	Air-sea interaction	ONR - SIO
FLIP Tug	ATF	5/2/69 to 5/30/69	FLIP service ship	COMSERVPAC
ASWEPS Aircraft	Super Constellation	6/7/69 to 6/21/69 7/7/69 to 7/21/69	Sea surface temperature and waves	NAVOCEANO
NRL Aircraft	Super Constellation	June 1969	Photographic wave spectrum	NRL
Weather Recon Aircraft	WC 121N	Alternate days BOMEX	Weather observations	WEARECON Squadron Four

Logistics

The Department of State has negotiated an agreement between the United States and the Government of Barbados covering BOMEX activities on the Island of Barbados.* The agreement provides for entry and exit of U.S. nationals, duty-free entry and exit of supplies and equipment, use of vehicles, lease of required work space, aircraft landing, servicing, and parking, and berthing of ships at Bridgetown. An operations center will be established by the BOMEX Project Office at Paragon House, Barbados.

Navy programs will be conducted under the BOMEX agreement. The deployment of Navy ships and aircraft, arrival and

*This agreement is contained in Diplomatic Note 70, Embassy of the United States, Bridgetown, Barbados, W.I., June 12, 1968.

departure of personnel and equipment, and communications traffic will be coordinated through a Navy representative at the BOMEX Operations Center on Barbados.

Funding

Funding estimates for the accomplishment of the Navy BOMEX plan are:

Contract Research Program*	$200,000
In-house Research Program	$295,000

The costs of ship and aircraft operations are not included in these estimates. Funding for the measurement programs is allocated under existing contract and in-house research programs.

NAVY ORGANIZATIONS PARTICIPATING IN BOMEX

The research programs forming the Navy participation in BOMEX draw upon the resources of a number of in-house and contract laboratories. The U.S. Navy Maury Center for Ocean Science, under the direction of Dr. J. B. Hersey, has the responsibility for coordinating the various experiments and measurement programs among Navy and contract laboratories, and integrating the programs with the BOMEX Project Office of the Environmental Science Services Administration. Research programs will be undertaken by the investigators from the Office of Naval Research contract research program, the Naval Research Laboratory, the Naval Oceanographic Office, the Naval Underwater Weapons Research and Engineering Station of the Naval Ordnance Systems Command, and the Naval Undersea Warfare Center of the Naval Ship Systems Command.

The various experimental programs proposed for the Navy participation in BOMEX are a part of the existing research

*The Contract Research Program figure includes only the additional research costs because of the BOMEX location. The contractors would be performing similar but uncoordinated research elsewhere, were it not for BOMEX.

programs. Thus, it is not necessary to establish any new management structure within which to organize the BOMEX effort. Personnel, equipment, and funding are the responsibility of the individual laboratories sponsoring the experiments.

It is anticipated, however, that platform scheduling, logistic arrangements, and data exchange will be major problem areas requiring coordination among investigators. As indicated, the Maury Center will provide the required coordination.

SUMMARY

The Navy participation in BOMEX is a combination of modified in-house and contract programs which stand to benefit by experiments conducted in a controlled observational network. These experiments in turn will make a significant contribution to the overall objectives of BOMEX. The programs in (a) thermal structure, (b) microscale energy processes, (c) surface-wave generation, (d) current-structure variability, and (e) environmental prediction evaluation are oceanographically oriented and span the field of interest to the Navy from basic processes to ASW predictions.

The Navy platforms from which the work will be conducted at the site east of Barbados in the late spring and early summer of 1969 are an oceanographic research ship (USNS GILLISS), two research aircraft, and the stable platform FLIP and its service tug. Additionally, a number of deep-ocean moorings will be emplaced to obtain time series data on currents and temperature structure.

Participation is being sponsored by the Office of Naval Research contract research program, the Naval Research Laboratory, the Naval Oceanographic Office, the Naval Underwater Weapons Center of the Naval Ship Systems Command, and the Naval Underwater Weapons Research and Engineering Station of the Naval Ordnance Systems Command. The U.S. Navy Maury Center for Ocean Science has the overall responsibility for developing the Navy plan and coordinating with the BOMEX Project Office of the Environmental Science Services Administration.

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7. "The ESSA Contribution to Phase II of the Federal Air-Sea Interaction Research Program," U.S. Department of Commerce, ESSA Inst. for Oceanography, Washington, D.C., Mar. 1967

APPENDIX
PARTICIPATION BY OTHER GOVERNMENT ORGANIZATIONS*

BOMEX, as a multi-facet field experiment will involve the talents and resources of many groups. While all commitments for participation have not been finalized pending the availability of funds and facilities, principal federal support has been proposed as follows.

DEPARTMENT OF COMMERCE

As noted previously, overall coordination is the responsibility of the Department of Commerce through the BOMEX Project Office which will serve as the focus for planning and coordinating the experiment.

Commerce's Environmental Science Services Administration has committed the Coast and Geodetic Survey vessels DISCOVERER, MT. MITCHELL, OCEANOGRAPHER, and SURVEYOR, and personnel and material support. Contracts have been awarded for a stabilized shipboard meteorological radar (Selenia) and three Windfinding at Sea Systems (Scanwell).

ESSA's Sea-Air Interaction Laboratory is engaged in the procurement and planning for the operation of a buoy network, boundary layer instrument packages, and other parameter measuring devices, with the full support of the Coast and Geodetic Survey marine engineering staff.

The Environmental Data Service of ESSA is providing support in data reduction, machine programming, formating, and compilation and archiving.

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*Excerpts from "BOMEX Bulletin No. 2," The BOMEX Project Office, 6010 Executive Blvd., Rockville, Md., May 14, 1968.

ESSA's Weather Bureau is providing engineering and other technical advice as well as commitments of personnel and material.

The ESSA National Environmental Satellite Center will provide a complete range of satellite observations and indirect sensing measurements. They seek as their objectives extensive ground truth testing based on surface observations of sea and air temperature, humidity, wind and sea state to compare with satellite pictures and infrared radiation data. They also desire vertical profile measurements for atmospheric attenuation studies and cloud observations from all-sky cameras and aerial photography to compare with satellite picture and radiation data.

ESSA's National Center for Atmospheric Research (NCAR) will participate in BOMEX in three ways: First, research projects conducted by members of the NCAR scientific staff as add-on experiments within the BOMEX framework; second, Facilities Laboratory support of individual research projects planned and conducted by university groups within BOMEX; and third, participation in the central planning activities of the project office.

NCAR plans to conduct at least two research projects within BOMEX. One is a continuation of their 1968 participation with Florida State University (FSU) in Barbados. The other is an effort to employ an aircraft system for measuring atmospheric fluxes. NCAR expects that the Cloud Physics and Atmospheric Dynamics (CPAD) aircraft will be available by 1969 for atmospheric dynamics observations.

ATOMIC ENERGY COMMISSION

AEC will measure the budgets, fluxes, and deposition rates of natural and weapons-produced radionuclides over the sea, and compare these to the water, momentum and heat budget measured by the BOMEX observation network. The steady-state deposition rate will be estimated by inventorying short-lived radionuclides in the ocean (using AEC laboratory equipment on the BOMEX ships) and equating their decay rate to

the deposition rate. Then this deposition rate will be used with the measured nuclide profiles in the air to help in understanding the mechanisms of vertical flux of the nuclides.

Because precipitation may substantially increase the vertical exchange of the nuclides, the AEC will also measure, for the first time, the scavenging efficiency of rain for the natural oceanic aerosol to which the radionuclides are attached. This will be feasible because the concentration of the radionuclides will be measured in the air which is being entrained into the rain clouds. Measurement of the precipitation, precipitation rates, drop sizes, electrical charges, and its chemical and radiochemical content will be undertaken by the AEC to help relate the field observations to laboratory experiments on scavenging. The AEC precipitation measurements will be correlated with the echoes on the BOMEX radar, which will assist in using the BOMEX radar coverage to evaluate the total precipitation in the test area. The total precipitation determination is needed for the water budget studies of BOMEX as well as in the evaluation of the total scavenging.

The AEC will provide a micrometeorological input to the program by measuring temperature and wind profiles at low levels. They may also use a research aircraft.

DEPARTMENT OF THE INTERIOR

The DOI through its Bureau of Commerical Fisheries Tropical Atlantic Biological Laboratory (TABL) plans to cooperate by scheduling the research vessel UNDAUNTED to operate west of St. Lucia, St. Vincent, and the Grenadines during BOMEX. They plan to occupy a grid of stations to define fields of temperature, salinity, and other parameters to depths of 500 meters. The vessel has been offered also as a meteorological platform if sensors and technicians can be provided.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

The Mississippi Test Facility of NASA's George C. Marshall Space Flight Center is planning extensive support in the areas

of test and calibration, data system planning and data reduction and processing. Although NASA will not launch a satellite specifically for BOMEX, they expect that several research satellites may still be furnishing useful data. These are Nimbus B, Tiros M, ATS III, and ATS D. In addition to the satellite objectives of the project, they have an interest in sensing oceanographic parameters *via* satellite.

NATIONAL SCIENCE FOUNDATION

The NSF will cooperate in BOMEX and plan to support selected proposals from the University scientists for well-planned field experiments that can be conducted within the framework of the BOMEX.

DEPARTMENT OF TRANSPORTATION

Transportation's U.S. Coast Guard has committed the cutter ROCKAWAY as an instrument platform and the buoy tender LAUREL* for buoy deployment and retrieval. The USCG has also accepted the responsibility for Search and Rescue (SAR) support for the operation. This will be provided by the San Juan sector coordinator utilizing the ROCKAWAY and the other BOMEX vessels.

NATIONAL OCEANOGRAPHIC DATA CENTER

NODC will provide support in oceanographic data processing and plans to provide personnel to aid in data handling design, scientific programming and formating.

DEPARTMENT OF DEFENSE (Other than Navy)

The DOD has authorized the Air Force, Army, and Navy to negotiate directly with the BOMEX Project Office concerning their objectives and commitments.

*Buoy tender CACTUS was originally scheduled for this mission

Air Force has submitted several scientific programs including convective cloud growth under an artificial cirrostratus deck over the island and ionospheric experiments. In the field of dynamics they plan to use BOMEX data for model development and simulation studies. Other objectives are the use of lightning locators to investigate the possibility of identifying lightning producing showers and thunderstorms, and to determine whether warm clouds produce lightning; a radar study of gust-producing showers and thunderstorms to determine characteristics which will hopefully be useful as a short-range forecasting tool. Equipment scheduled for testing and use are the Air Force Cambridge Research Laboratories expendable dew point hygrometer, and low-level sounding system. The Air Weather Service dropsondes modified for sea-surface temperature observation will also be tested.

The Air Force has conditionally committed low, medium and high altitude reconnaissance aircraft for vertical and horizontal observations, particulate and gaseous sampling, and panoramic color photography of the experiment area. Five mobile rawinsonde teams with equipment for shipboard and island stations have been conditionally committed.

Army objectives are primarily the relation of the air-sea interaction to the design and operation of hurricane protection, beach erosion control and harbor projects. Another objective is in atmospheric radiation and aerosol size measurements over the tropical ocean as they pertain to tropical precipitation measurements. The Army has pledged cooperation within available resources upon request.